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EFFECTS OF POWER TRANSMISSION LINES ON VEGETATION OF THE MOJAVE DESERT

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The natural vegetation of the Mojave Desert has been subjected to a variety of manmade disturbances including construction activity, agricultural clearing, recreational traffic, military maneuvers and testing, mining, and many more. Disturbance activities have a primary impact at their onset and sometimes a secondary impact if disturbance continues. An assessment of disturbance to vegetation involves estimating both the area disturbed and the species affected, along with evaluating the course and rate of recovery. In cases compounded by continued disturbance, many secondary effects may develop that may cause drastic changes in the distribution of organisms and in organism interactions.

There are a few reports discussing the impact that various disturbances have had on the Mojave Desert vegetation. Beatley (1965, 1966) and Wallace and Romney (1972) discussed the effect of short-term disturbance on the vegetation of nuclear test sites in southern Nevada. Vasek et al. (1975) described the effect of pipeline construction in the Lucerne Valley region of California, and called attention to the extreme ages of some creosote bushes *(Larrea tridentata)*. Wells (1961) described a successional pattern following the cessation of continued disturbance on the streets of a Nevada ghost town, and Davidson and Fox (1974) evaluated the effects of intermittent off-road motorcycle activity. However, to our knowledge, no evaluations are available on the disturbance to vegetation by powerline construction.

The construction of power transmission lines involves clearing access roads, constructing pylons, and stringing cables and wires between pylons. Disturbance ceases after construction is complete, except for continued use of access roads by maintenance patrols. In essence, then, power line construction involves devegetation on access roadways, temporary destruction of vegetation under the power pylons, and temporary disturbance of vegetation between pylons by trampling. Our report attempts to estimate the impact of power transmission line construction and maintenance on the vegetation of the Lucerne Valley region of the Mojave Desert. The investigation was supported by the Southern California Edison Company as part of an environmental impact study associated with their proposal for a new electric generating plant in the Lucerne Valley region of San Bernardino County, California.

METHODS

We selected two existing Southern California Edison power transmission lines in the Lucerne Valley region for study: the North Lugo to Pisgah 220 KV transmission line constructed in 1937, and the older of the twin lugo to Eldorado 550 KV transmission lines completed in 1970 and 1971 (fig. 1). Our method was to sample vegetation on and near the right of way at each of six study areas along the 1937 transmission line and five study areas along the 1970 transmission line. Physical characteristics of the study areas are listed in Table 1. Each study

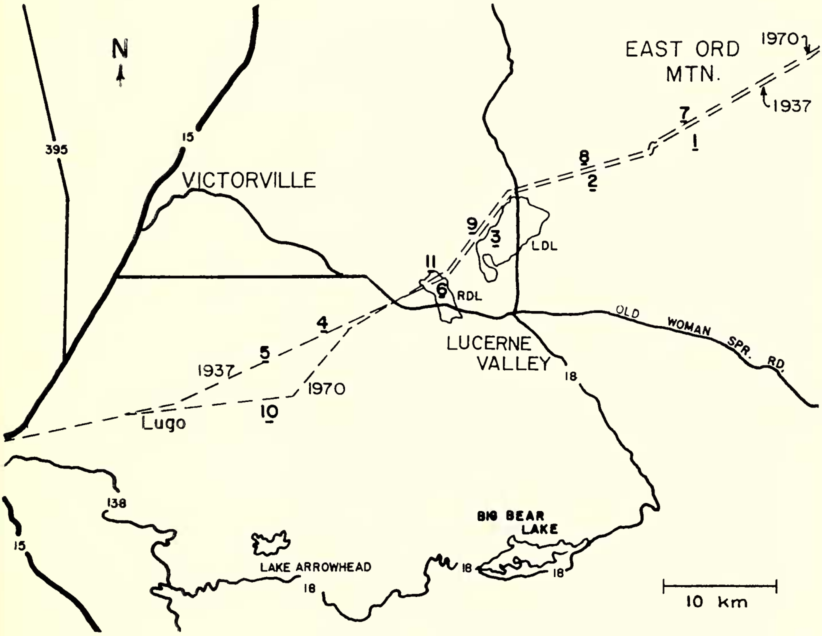

FIG. 1. The greater Lucerne Valley region (San Bernardino Co.) of Southern California showing the paths of power lines studied and the location of the areas sampled. The dashed line with study area sequence 5, 4, 6, 3, 2, and 1 represents the powerline constructed in 1937. The dashed line with study area sequence 10, 11, 9, 8, and 7 represents the power lines constructed in 1970–71. Local highway numbers and other landmarks are indicated. RDL = Rabbit Dry Lake; LDL = Lucerne Dry Lake.

TABLE 1. PHYSICAL CHARACTERISTICS OF STUDY AREAS.

Study areas	Power line	Topographic location	Exposure slope	Surface stability	Substrate origin	Substrate composition	Surface heterogeneity	Elevation (meters)
1, 7	Both	Rocky wash	South, gentle	Active erosion	Flood alluvium	Rocky to sandy	High	1036
2, 8	Both	Fan	Gentle	Stable	Alluvium	Sandy gravel	Low	940
3, 9	Both	Near dry lake	Level	Stable	Alluvium	Silt to sand	Moderate	883
4	Old	Valley bottom	Level	Stable	Alluvium	Sandy gravel	Low	990
5	Old	Valley bottom	Level	Stable	Alluvium	Sandy gravel	Low	960
10	New	Fan	North, moderate	Stable	Alluvium	Sandy gravel	Low	1100
6, 11	Both	Edge of dry lake	Level	Stable	Alluvium	Silt	Low	900

area was considered a separate experiment, the total representing a spectrum of disturbances. At each study area we sampled four belt transects, 100 m long and 2 m wide. The four transects were established as follows: transect A, a control transect at least 50 m away from the power line in undisturbed vegetation; transect B, midway between two pylons and directly under the central transmission wire; transect C, at the edge of the access road; and transect D, directly under the pylons. Since the pylons do not constitute a linear belt area, data from several consecutive pylons were pooled until a 200 m^2 area equal to each belt transect was sampled. Therefore, the area under four different pylons on the old powerline or the area under two consecutive pylons on the new powerline was included as one transect. The two selected powerlines provide a 33-year comparison reference frame and enable a reasonable estimate of vegetation recovery time for this type of disturbance.

Our observations are restricted to shrubs and suffrutescent perennials because samples were taken in mid-summer when herbaceous perennials and annuals were essentially absent. Therefore, in this paper ground cover refers to perennial ground cover by shrubs and suffrutescent perennials. The diameter of each shrub or suffrutescent perennial was measured directly in centimeters. Assuming that, on the average, plants cover a circular ground area, the ground cover for each plant was calculated from its radius and summed for each species in each transect. Our primary information, therefore, consists of plant density, ground cover, and species composition for each transect. In our analysis of the data, each perennial species is classified in one of two functional groups, long-lived or short-lived (Vasek et al., 1975), as determined from the literature (Muller, 1953; Muller and Muller, 1956) and our judgment. Percent ground cover of each functional group and of several important constituent species is calculated for each transect. Transects are then compared by a Community Quality Index (CQI) based on total perennial ground cover and the proportion of ground cover occupied by long-lived species (Vasek et al., 1975). The Community Quality Index (CQI) takes into account a measure of site productivity and an estimate of relative community age, thus providing an objective estimate of the ecological value (Suffling et al., 1974) of a vegetation. We judge dense vegetation of mature long-lived plants to be more valuable and have higher quality (CQI) than sparse vegetation of quick growing pioneers (low CQI).

For purposes of general comparison, we observed ten other transects representing undisturbed vegetation south and west of East Ord Mountain (fig. 1).

RESULTS

Regional Vegetation

Predominant vegetation in the Lucerne Valley region belongs to the creosote bush scrub community (community nomenclature of Munz and Keck, 1949). It occurs generally on slopes, alluvial fans, valley flats, washes, and on low mountains. In alkaline seeps and valley bottoms the creosote bush scrub community is often replaced by a salt bush scrub community (a departure from Munz's community nomenclature due to our preference for naming plant communities and vegetation after plants rather than topographic features) presumably because of the high salt content of the soil. At higher elevations it is replaced by either pinyon-juniper or joshua tree woodlands, probably in response to more favorable rainfall and moisture conditions.

In the Lucerne Valley region, creosote bush scrub vegetation is highly variable. Its composition in terms of relative vegetation cover ranges from about 19 to 98 percent *Larrea tridentata* (species nomenclature follows Munz, 1974) as shown in ten representative transects from the region south and west of East Ord Mountain (Table 2). The total perennial ground cover of these ten reference transects ranges from about 7 to 27 percent. The number of perennial plants ranges from 7 to 45 per 100 m^2 and these include from 3 to 12 species. Similar variation was observed by Beatley (1974) in the Mojave Desert of southern Nevada where perennial ground cover ranged from 7 to 23 percent for 23 plots in creosote bush communities and, of that cover, 9 to 85 percent was provided by *Larrea*. Variation in average plant density from 1 to 100 per 93 m^2 plot was reported by Woodell et al. (1969) for eight scattered Mojave Desert localities.

The amount of ground cover provided by *Ambrosia dumosa,* a common associate of *Larrea,* ranges from 0 to 18.3 percent (Table 2). Long-lived species, including *Larrea* and *Ambrosia,* contribute about 60 to 100 percent of the total perennial plant cover. Other long-lived species (observed on the ten reference transects) that form a significant fraction of the ground cover on at least one of the reference transects belong to such genera as *Krameria, Lycium, Cassia, Ephedra, Opuntia,* and *Atriplex* (Table 3). The major short-lived species (in terms of density and ground cover) is *Hymenoclea salsola.* Other short-lived species listed in Table 3 constitute less than 1 percent of the total cover. The plant cover provided by short-lived species on the ten reference transects ranges from 0 to about 34 percent, mostly provided by *Hymenoclea.* Variation among these ten transects is quite apparent and can be partly explained by habitat differences (Table 2). The general characteristics of each transect can be summarized in one number, the Community Quality Index. Indices, ranging from 24 to 50 (Table 2), are rather high as compared to CQI's for creosote bush scrub communities in the mountainous region to the north. Vasek et al. (1975) found CQI ratings up to 44 in the Lucerne Valley region but north of the Ord Mountains ratings ranged from 15 to 28.

Vegetation Along Power Lines

The powerlines in the Mojave Desert region under study mostly traverse creosote bush scrub vegetation (study areas 1–5 and 7–9). How-

Table 2. Analysis of Regional Vegetation based on 10 Reference Transects South and West of East Ord Mountain. TR = transect sample number; GC = ground cover; Density = number of individual plants; LL = long-lived species; SL = short-lived species; CQI = Community Quality Index.

TR	Total perennial GC%	Density per 100 m²	Number of species	Relative plant cover (% of total)						CQI	Site
				Larrea	*Ambrosia*	Other LL	All LL	All SL	*Hymen-oclea*		
31	10.69	11.5	5	36.67	0.00	36.20	72.87	27.13	27.13	27.91	Rocky wash
33	16.32	25.5	5	54.42	0.00	22.49	76.91	23.09	20.98	34.10	Rocky wash
43	10.74	21.0	5	89.29	2.79	7.49	99.53	0.47	0.00	32.69	Rocky alluvial slope
45	6.96	22.5	3	89.08	10.63	0.00	99.71	0.29	0.00	26.34	Silty wash
44	12.94	7.0	3	97.91	0.15	1.93	100.00	0.00	0.00	35.97	Sandy bajada
46	18.87	43.5	5	63.36	18.27	11.23	92.86	7.14	7.14	42.06	Sandy bajada
48	27.48	45.0	12	55.06	0.18	23.51	78.75	21.25	20.82	46.52	Gravelly wash
47	9.86	26.0	10	19.37	1.42	38.95	59.74	40.26	34.38	24.27	Gravelly wash
52	16.04	26.5	8	37.97	7.17	46.57	91.71	8.29	8.23	38.35	Silty wash
53	26.07	27.5	6	54.09	5.18	39.85	99.12	0.88	0.35	50.83	Silty wash

TABLE 3. PERENNIAL PLANT SPECIES CLASSIFIED BY RELATIVE AGE SPAN AND LISTED IN ORDER OF DECREASING TOTAL GROUND COVER FOR THE TEN REFERENCE TRANSECTS. (See Table 2; combined area = 2,000 m^2.) LL = long-lived perennial; SL = short-lived perennial; (?) = some uncertainty regarding age span.

SPECIES	Total coverage (m^2)	Relative age
Larrea tridentata	179.86	LL
Hymenoclea salsola	35.94	SL
Atriplex polycarpa	21.28	LL
Ambrosia dumosa	15.98	LL
Lycium cooperi	10.76	LL
Lycium andersonii	10.24	LL
Atriplex canescens	5.72	LL
Krameria parvifolia	5.58	LL
Opuntia ramosissima	4.96	LL
Cassia armata	2.40	LL
Salazaria mexicana	3.92	(?)
Ephedra californica	3.70	LL
Yucca schidigera	3.06	LL
Acacia greggii	2.26	LL
Encelia farinosa	1.20	LL
Stephanomeria pauciflora	0.88	SL
Thamnosma montana	0.78	LL
Sphaeralcea ambigua	0.42	SL
Chrysothamnus paniculatus	0.40	LL
Eriogonum inflatum	0.30	SL
Echinocereus engelmannii	0.08	LL
Opuntia basilaris	0.08	LL
Opuntia echinocarpa	0.04	LL
Haplopappus cooperi	0.04	SL
Machaeranthera tortifolia	0.02	SL
Fagonia californica	0.02	SL

ever, in the bottom of Lucerne Valley (study areas 6 and 11) they cross two dry lakes in alkali sinks with salt bush scrub vegetation, and west of Lucerne Valley (study area 10) they traverse various scrub woodland communities dominated by Joshua Trees *(Yucca brevifolia)* or California Junipers *(Juniperus californica)*. Data for the salt bush scrub (areas 6 and 11) are presented separately (Table 6) because the habitat and the plant community on the dry lake differ considerably from the creosote bush scrub community and its habitats and because a complete set of four transects for each powerline was not obtained. The road edge transects and a transect under the wire were located on the dry lake playa and consequently had no plant cover. As a result the dry lake vegetation data include one control transect, one transect under the wire of the 1937 powerline, and the vegetation under the two sets of pylons.

1937 Power Line

Vegetation sample data for the 1937 powerline are analyzed in Table 4. Total perennial ground cover for the 20 transects representing the 1937 powerline range from about 11 to 57 percent. Ground cover on control transects ranges from 11 to 13 percent except in study area 3 where it is 20 percent. Ground cover on the transect under the central wire is slightly higher than the control in the first three study areas, significantly higher in study area 4, and approximately the same in study area 5. Ground cover along the road edge is substantially greater than control values in all study areas and greater than under the central wire in four of the study areas. Total perennial ground cover under the pylons shows the greatest variation, ranging from considerably less than control values (area 3), to slightly above control values (area 2), to substantially above control values (area 1), and finally to over four times control values (area 4). In most study areas, the number of plants on transects A, B, and C are approximately the same while a two- to three-fold increase in plant number is evident in transect D under the pylons. The proportion of *Larrea* decreases under the pylons (transect D) as compared with the other three transects. Interestingly, the proportions of *Ambrosia* sometimes increase under the pylons and, in the first three study areas, decrease drastically under the central wire. The latter observation suggests that *Ambrosia* is easily decreased by trampling. Its increase under the pylon (study area 1) suggests that it has a greater pioneer capacity than does *Larrea*. All the long-lived perennials taken together show a pattern of high total ground cover on the first three transects and then a slight to moderate decrease on the transects under the pylon. A reciprocal relationship is evidenced by *Hymenoclea* and other short-lived perennials, namely, their presence in relatively small proportions on the first three transects and an increase in proportion of ground cover under the pylons. Finally, the Community Quality Index for the 20 transects ranges from 32 to 57 (Table 4). Generally the control transect has the lowest or very close to the lowest CQI for all five areas. Transects along the road edge and under the wire have CQI's at least as high as the control and in most cases higher, while transects under the pylons are the most variable with CQI values ranging from less than control (sample area 3) to substantially above control (sample area 4). These CQI values compare quite well with those of the ten reference transects (Table 2), which had values from 24 to 50 over a greater diversity of terrain.

1970 Power Line

An analysis of the vegetation sample data for the four study areas along the 1970 powerline (Table 5) indicates a range in total perennial ground cover between 1 and 48 percent. The most conspicuous pattern is a marked decrease in ground cover under the pylons (Transect D), while transects under the wire and at the road edge (B and C) generally have greater ground cover than the control. Approximately the same numbers

TABLE 4. ANALYSIS OF VEGETATION ALONG A POWER LINE CONSTRUCTED IN 1937. TR = transect; A = control; B = wire; C = road edge; D = pylon; GC = ground cover; LL = long-lived species; SL = short-lived species; CQI = community quality index.

TR	% Total GC	Density per 100 m^2	Number of species	% of total GC provided by						CQI
				Larrea	*Ambrosia*	Other LL	Total LL	*Hymen-oclea*	Total SL	
Study area 1										
A	11.75	48.0	4	45.02	47.57	7.40	100.00	0.00	0.00	34.28
B	15.49	41.5	2	85.86	14.14	0.00	100.00	0.00	0.00	39.38
C	19.51	38.0	3	69.20	28.81	2.00	100.00	0.00	0.00	44.17
D	21.33	56.5	4	20.96	70.18	0.09	91.23	8.77	8.77	44.11
Study area 2										
A	11.13	38.5	3	44.20	54.09	0.00	98.29	1.71	1.71	33.08
B	17.18	36.5	5	77.59	20.90	0.93	99.42	0.58	0.58	41.33
C	16.85	40.0	2	70.33	29.67	0.00	100.00	0.00	0.00	41.09
D	11.59	62.5	4	39.86	50.22	0.00	90.08	5.78	9.92	32.31
Study area 3										
A	20.24	39.5	6	55.39	23.62	20.45	99.46	0.00	0.54	44.87
B	21.95	41.0	7	61.96	11.34	25.83	99.13	0.50	0.87	46.65
C	24.03	45.5	8	49.18	24.53	26.13	99.84	0.00	0.16	49.99
D	13.15	99.5	6	15.74	14.90	58.48	89.13	10.87	10.87	34.23
Study area 4										
A	13.23	17.5	11	70.21	7.16	19.68	97.05	0.00	2.94	35.87
B	29.98	49.0	7	41.76	8.74	37.16	87.66	0.00	12.34	51.26
C	32.55	42.5	15	45.41	2.12	38.46	85.99	2.15	14.01	52.91
D	57.18	128.5	11	23.15	1.63	32.77	57.56	10.49	42.44	57.37
Study area 5										
A	12.45	25.0	4	70.36	23.53	3.05	96.95	0.00	3.05	34.74
B	12.06	23.0	6	73.80	18.41	5.97	98.18	0.00	1.82	34.41
C	33.11	31.0	5	81.24	3.02	12.72	96.98	0.00	3.02	56.67
D	19.03	53.5	7	42.09	8.62	30.37	81.08	0.00	18.92	39.28

TABLE 5. ANALYSIS OF THE VEGETATION ALONG A POWEE LINE CONSTRUCTED IN 1970. Headings as in Table 4.

TR	% Total GC	Density per 100 m^2	Number of species	% of total GC provided by *Larrea*	*Ambrosia*	Other LL	Total LL	*Hymen-oclea*	Total SL	CQI
Study area 7										
A	25.55	62.5	4	81.53	14.91	3.56	100.00	0.00	0.00	50.55
B	15.97	52.5	3	63.56	35.94	0.50	100.00	0.00	0.00	39.96
C	35.46	62.5	4	67.18	31.84	0.00	98.96	0.82	1.04	59.24
D	8.94	35.5	3	41.39	54.25	0.00	95.64	4.36	4.36	29.24
Study area 8										
A	9.66	37.0	3	55.07	44.41	0.00	99.48	0.52	0.52	31.00
B	15.27	43.0	4	79.90	16.50	2.95	99.35	0.65	0.65	38.95
C	16.85	40.0	2	70.33	29.67	0.00	100.00	0.00	0.00	41.09
D	1.46	9.0	4	62.33	34.25	0.68	97.26	0.00	2.74	11.92
Study area 9										
A	20.24	40.0	6	55.39	23.62	20.45	99.46	0.00	0.54	44.87
B	22.77	45.0	9	69.78	15.33	14.40	99.52	0.00	0.48	47.60
C	25.03	45.5	8	49.18	24.53	26.13	99.84	0.00	0.16	49.99
D	9.27	88.0	5	17.48	17.04	65.48	100.00	0.00	0.00	30.45
Study area 10										
A	28.21	53.0	10	0.00	0.00	49.81	49.81	17.26	50.19	37.49
B	43.64	100.5	11	0.00	0.00	48.79	48.79	19.52	51.21	46.14
C	48.39	100.5	11	0.00	0.00	62.16	62.16	19.48	37.84	54.84
D	14.66	58.0	9	0.00	0.00	24.83	24.83	11.80	75.17	19.08

TABLE 6. ANALYSIS AND EVALUATION OF PLANT COVER SAMPLES FROM RABBIT DRY LAKE. (Study areas 6 and 10). TR = transect; A = control; B = wire; D = pylon; GC = ground cover; LL = long-lived perennials; SL = short-lived perennials; CQI = community quality index.

				% of total GC provided by						
TR	Total GC %	Density per 100 m²	Number of species	*Atriplex confertifolia*	*Atriplex polycarpa*	*Suaeda fruticosa*	Other LL	Total LL	*Atriplex lentiformis* (Total SL)	CQI
A	17.09	47.0	7	55.65	6.09	21.30	16.99	100.00	0.00	41.34
B	16.05	67.5	5	47.48	9.22	32.02	11.28	100.00	0.00	40.06
(1937) D	10.42	16.0	4	31.67	0.38	43.67	0.00	75.72	24.28	28.09
(1970) D	9.76	63.5	6	43.75	36.48	1.95	0.41	82.58	17.42	28.49

of plants occur on the first three transects, except in study area 10 where transects B (wire) and C (road edge) have a greater number of plants and greater ground cover. On transect D (pylon) plant number decreases drastically in study areas 7 and 8 but increases substantially in study area 9 and remains just slightly above control levels in study area 10. The number of species observed on the several transects is about the same as for the other powerline. Long-lived perennials provide essentially all of the ground cover in all transects of the first three study areas. The virtual absence of pioneer species is rather surprising in view of their noticeable presence on the older powerline. However, the short period between completion of the powerline and the observations recorded in these data may have precluded the establishment of pioneer shrubs to any substantial degree. The long-lived plants under the pylons, then, may be residual; that is, the very large area covered by the new-style pylons on the 1970 line may not have required complete clearance for pylon construction as was probably the case with the older pylons. In any event, the proportion of short-lived species is relatively small, reaching over 4 percent only under the pylons in study area 7. Study area 10 deserves special mention here, because of the complete absence of *Larrea* or *Ambrosia* on any of the four transects. The long-lived species of the creosote bush scrub community comprise only about half the ground cover in this study area, which is located at the edge of the Joshua-Juniper scrub woodland and really not in a creosote bush scrub community. The Community Quality Index for each of the 16 transects (Table 5) ranges from approximately 12 to 59. Thus the range of CQI values is comparable to that of the 1937 powerline, except CQI values for the vegetation under pylons are substantially lower, indicating severe disturbance by pylon construction.

Alkali Sink Vegetation

The vegetation in the salt bush scrub community of the alkali sink at Rabbit Dry Lake (areas 6 and 11) has several interesting and noteworthy aspects. First, the control transect and the transect under the central wire of the 1937 powerline (Table 6) are quite comparable with respect to total ground cover, number of species, proportion of ground cover provided by a major long-lived species, the absence of ground cover provided by short-lived species, and the CQI. They differ slightly in the number of plants per 100 m^2 area. The two transects comparing vegetation under the pylons of the 1937 and the 1970 powerlines are closely similar and stand in contrast to the two other transects. The two pylon transects are comparable with respect to the total perennial ground cover, the number of species present, the proportion of ground cover provided by *Atriplex confertifolia,* the total ground cover by all long-lived species, the ground cover provided by *Atriplex lentiformis* (short-lived species), and the CQI. The two transects differ somewhat in that the vegetation under the 1937 pylons comprises a few large plants while the vegetation under the 1970 pylons is made up of a large number of small plants. Another striking difference is that *Atriplex polycarpa* is sparingly present under the 1937 pylons, yet comprises 36 percent of the ground cover under the 1970 pylons. In contrast, *Suaeda fruticosa* contributes 43 percent of the ground cover under the 1937 pylons and only 1.95 percent under the 1970 pylons. Both are present with intermediate ground coverages in the control transect. A strong pioneer role under the 1970 pylons near Lucerne Dry Lake (area 3) suggests that *Atriplex polycarpa* (cited in Table 4 under "other LL") may have a more definite pioneer role in a salt sink situation than it does elsewhere. In any event, the successional status, the age span characteristics under different environmental conditions, and the general ecophysiological response patterns of *Atriplex polycarpa* need further study. Some of the puzzling circumstances might possibly be explained, if we knew the season in which pylon construction was completed and germination conditions (i.e., rainfall) became favorable. In the absence of that information, further attempts at explanation are not warranted.

Discussion and Evaluation

Evaluation of the impact of powerline construction and operation may be approached in several ways. Visual scanning of Tables 4 and 5 shows that plant number increases on the old powerline and usually decreases on the new powerline with increased disturbance and that the proportion of ground cover provided by short-lived perennials is usually higher on sites of severe disturbance (under pylons).

A second approach to the evaluation of the impact of powerline construction involves comparisons of the Community Quality Index among several transects. Community Quality Indices for the two powerlines are accumulated in Table 7 for comparison. The apparent pattern for the 1937 line is that the central wire transect has a substantially higher CQI than does the control, except in study area 5. Additionally, transect C at the road edge has a CQI higher than transect B, and is also higher than transect A, except in sample area 2. Greater variation is evident under the pylons where the CQI may be highest (area 4), approximately as high as the road edge transect (area 1), an intermediate value (area 5), approximately equal to control level (area 2), or considerably below control level (area 3). On the average, however, the CQI for transect D (pylons) approximates that of transect B and remains somewhat above the control level. The greater range of variation in transect D, again, is notable.

Similar analysis for the 1970 powerline also shows the pattern of increasing CQI through transects A, B, and C, except in study area 7 where the control transect registered an unusually high CQI due to high ground cover. Except for the high CQI in area 7, the pattern for A, B, and C closely approximates that for the 1937 line. With regard to transect D, under the pylons, a considerably lower CQI is registered in every

TABLE 7. COMMUNITY QUALITY INDICES FOR VEGETATION SAMPLES ALONG TWO POWER LINES. Areas 1–5 1937 line; areas 7–9 1970 line; A, control; B, wire; C, road edge; D, pylon;

$$\mathrm{CQI} = \sqrt{\%\ \text{total perennial cover} \times \%\ \text{of total perennial cover by long-lived species}}$$

Area	Transect				Area	Transect			
	A	B	C	D		A	B	C	D
1	34.28	39.38	44.17	44.11	7	50.55	39.96	59.24	29.24
2	33.08	41.33	41.09	32.31	8	31.00	38.95	41.09	11.92
3	44.87	46.65	49.99	34.23	9	44.87	47.00	49.99	30.45
4	35.87	51.26	52.91	57.37	10	37.49	46.14	54.84	19.08
5	34.74	34.41	56.67	39.28					

study area, averaging only about half that of the control level. From these comparisons, a general and probably significant increase in the CQI is evident in the vegetation under the central wire and at the road edge. The vegetation under the pylons 33 years after disturbance is quite variable, having a quality ranging from lower than the control to higher than the control. However, only a few years after disturbance, the quality (CQI) of the vegetation under the pylons is consistently very low. At this point, stands of vegetation may be judged to be better or worse than other stands in terms of ecological quality by comparing CQI values.

The effects of the several treatments, as represented by the four different classes of transects, appear to be significant. But inspection of Table 7 suggests some differences in the levels of CQI from one study area to another, in addition to some differences between samples on the two powerlines within a given study area. To sort out these possible effects, a three-way analysis of variance (Sokal and Rohlf, 1969) was undertaken for the CQI values listed in Table 7. Since greater convenience of computation is permitted by having equal numbers of entries in the data matrix, the four study areas of the 1970 line were compared with only four of the study areas of the 1937 line. Study area 5, rather than study area 4, of the 1937 line was selected for comparison with study area 10 of the 1970 line because it was judged more comparable. A first analysis of variance compared four study areas in each of the two powerlines (1, 2, 3, 4 vs. 7, 8, 9, 10) and then, because the two powerlines run together only through three study areas, a second analysis of variance compared only the data from three study areas (1, 2, 3 vs. 7, 8, 9) on each powerline in a 2 by 3 by 4 data matrix. Results of those two analyses of variance are shown in Table 8. The patterns are similar in both

TABLE 8. THREE-WAY ANALYSIS OF VARIANCE FOR CQI VALUES IN TABLE 7. MS = mean square; F = variance ratio; Sig. = relative significance; NS = not significant; *, **, *** = significance respectively at the 0.05, 0.01, and 0.001 levels of probability.

Source of variation	Four Sample Areas			Three Sample Areas		
	MS	F	Sig.	MS	F	Sig.
Main effects						
A—power lines	32.87	1.16	NS	4.70	....	NS
B—transects	522.44	18.42	***	311.37	13.27	**
C—study areas	153.64	5.42	*	230.15	9.81	*
First order interaction						
A X B	17306.24	610.66	***	12916.29	550.80	***
A X C	17176.39	606.08	***	19268.92	821.70	***
B X C	5746.28	202.76	***	6429.57	274.18	***
Second order interaction						
A X B X C	28.34	....	......	23.45	....	......

analyses and can be discussed as one. As a direct source of variation among CQI values (Table 8), the two powerlines are not significant. Differences attributable to the several study areas, however, are significant ($p < 0.05$). The direct effects attributable to the different transects are significant at the 1 percent probability level for the three sets of paired study areas and at the 0.1 percent level of probability for the four study areas. Of great interest, however, is that the first order interaction between any two pairs of variation sources is highly significant at the 0.1 percent level of probability in both analyses. We interpret the direct effects to mean that the vegetation of the two powerlines is the same, even when combining all the variations from all sources into one comparison. We also interpret the variation between study areas to be significant, but not overriding; but, the variation among transects (or treatments of the vegetation due to powerline construction and operation) is large and highly significant. We interpret the first order interaction results to mean that disturbance of something as complex as vegetation has highly significant effects, far greater than would have been predicted from separate consideration of the individual factors, and that response to treatment differs with regard to both space and time. These analyses of variance, therefore, confirm and extend the conclusions reached by other approaches. Namely, the greater disturbance associated with pylon construction imparts a greater variation and hence lack of predictability to vegetational response than does less severe disturbance such as trampling under the central wire.

In general, then, the effect of the construction and operation of transmission powerlines is one of a slight enhancement of the vegetation, i.e., an increase in cover under the central wire, somewhat greater enhancement of the vegetation along the road edge, and a highly variable response of the vegetation under the plyons. Reasons for enhancement of the vegetation under the central wire are conjectural at this time. However, one possibility is that moisture from clouds, fog, and rain may be concentrated toward the low point of the sagging wire and there drips off to the ground. Explanations for the enhancement of vegetation at the road edge are probably two. One involves drainage off the road or road edge accumulation of ordinary down-slope drainage. However, our observations indicate enhancement of road edge vegetation also occurs in areas where such obvious drainage factors do not apply. The second explanation involves removal of competition by plants that formerly were located on the roadway. Whether other factors pertain is at this point problematical.

Reasons for the decrease in vegetation under the pylons are of course related to mechanical removal or drastic disturbance during construction. Revegetation occurs to the extent that after 33 years disturbance effects are still detectable, but the quality of the recovering vegetation approaches that of the surrounding vegetation. Variability is greater than that of the surrounding vegetation, suggesting low predictability concerning the time course of vegetative recovery. The reasons for low predictability are perhaps several and may relate to such factors as the thoroughness of mechanical removal, the depth of soil disturbance, and the species that happen to be the first invaders. The latter, in turn, may have been influenced by seasonal and climatic conditions at the time disturbance ceased, and by the seed source available for invasion. We suspect a different course of succession would follow depending upon whether initial pioneer invasion occurred following summer, versus winter, rain. Predictability probably also depends upon the age span of the particular pioneer species that happened to colonize a given pylon site. Clearly plants like *Eriogonum fasciculatum* or *Atriplex polycarpa* would be longer-lived pioneers than plants like *Euphorbia polycarpa* or *Stephanomeria pauciflora*. The need for more careful definition of relative age span is obvious. In any event, predictability following the fairly drastic disturbance of pylon construction is relatively low.

The overall and long-term effects of powerline construction and operation, then, are: a permanent legacy of a devegetated maintenance road; variable, but fairly regular, road edge enhancement of vegetation; slight enhancement of vegetation between power pylons; and a drastic disturbance immediately under the pylons from which vegetation recovers significantly but not completely after about 33 years.

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ADDITIONS AND CORRECTIONS TO A REVIEW OF NORTH AMERICAN PACIFIC COAST BEACH VEGETATION

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Breckon and Barbour (1974) recently reviewed the literature on beach vegetation of the Pacific Coast of North America. Subsequent field observations verified many of their conclusions about structure and distribution of beach communities and revealed new information requiring corrections and reconsideration of some of their conclusions. Our survey ranged from Washington (approximately 48° N latitude) to Cabo San Lucas, Baja California (23° N).

For the sake of brevity, additions, corrections, and deletions for the list of characteristic beach species are summarized in text. The interested